6th INTERNATIONAL SYMPOSIUM ON

NORM VI

NATURALLY OCCURRING RADIOACTIVE MATERIA

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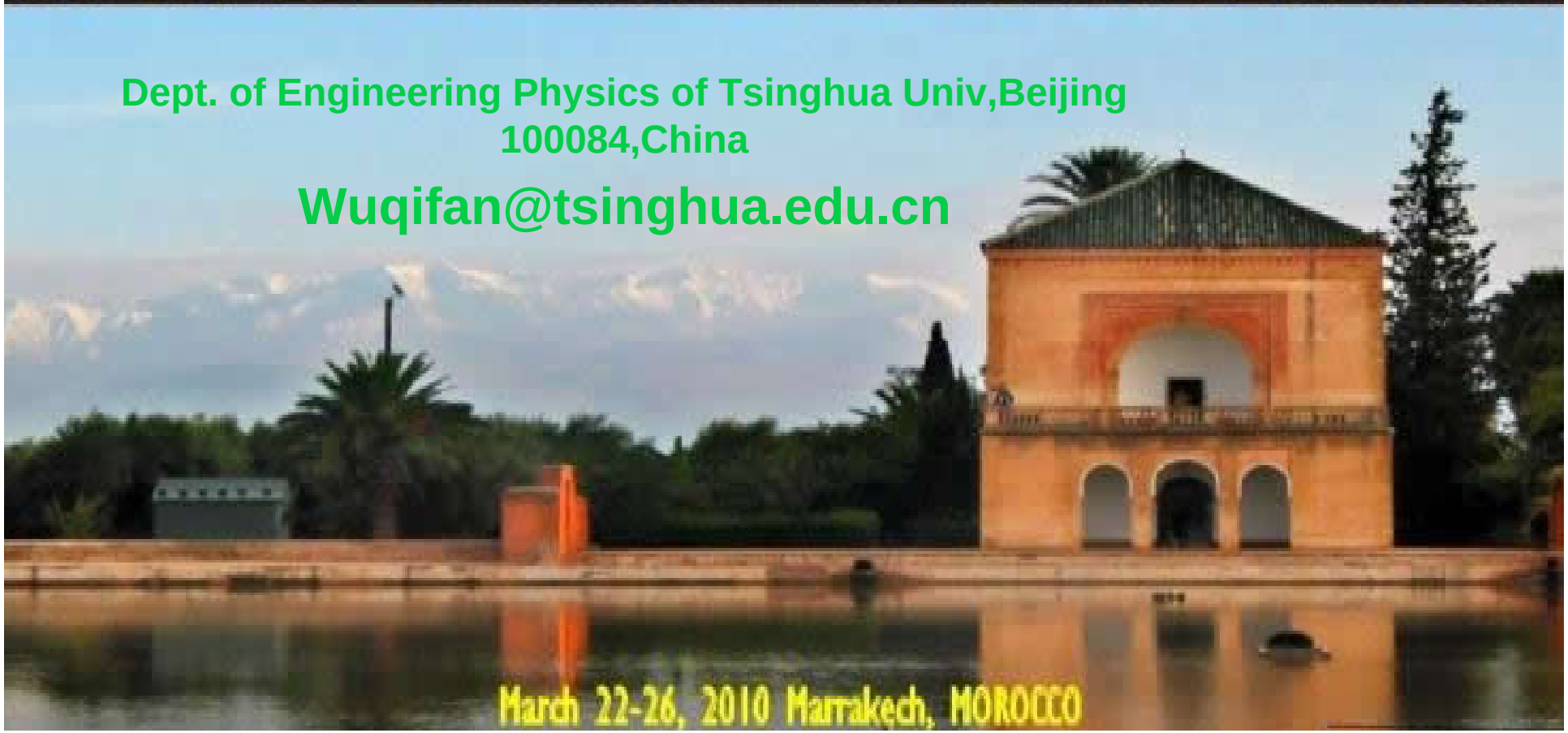

The use and management of NORM residues in processing Bayan Obo ores in China

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Industrial sectors involved NORM or TENORM

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- **Metal Mining and Processing Waste**
- **Geothermal Energy Production Waste.**
- **Paper and pulp Industry**
- **Scrap Metal Release and Recycling**

1. Introduction

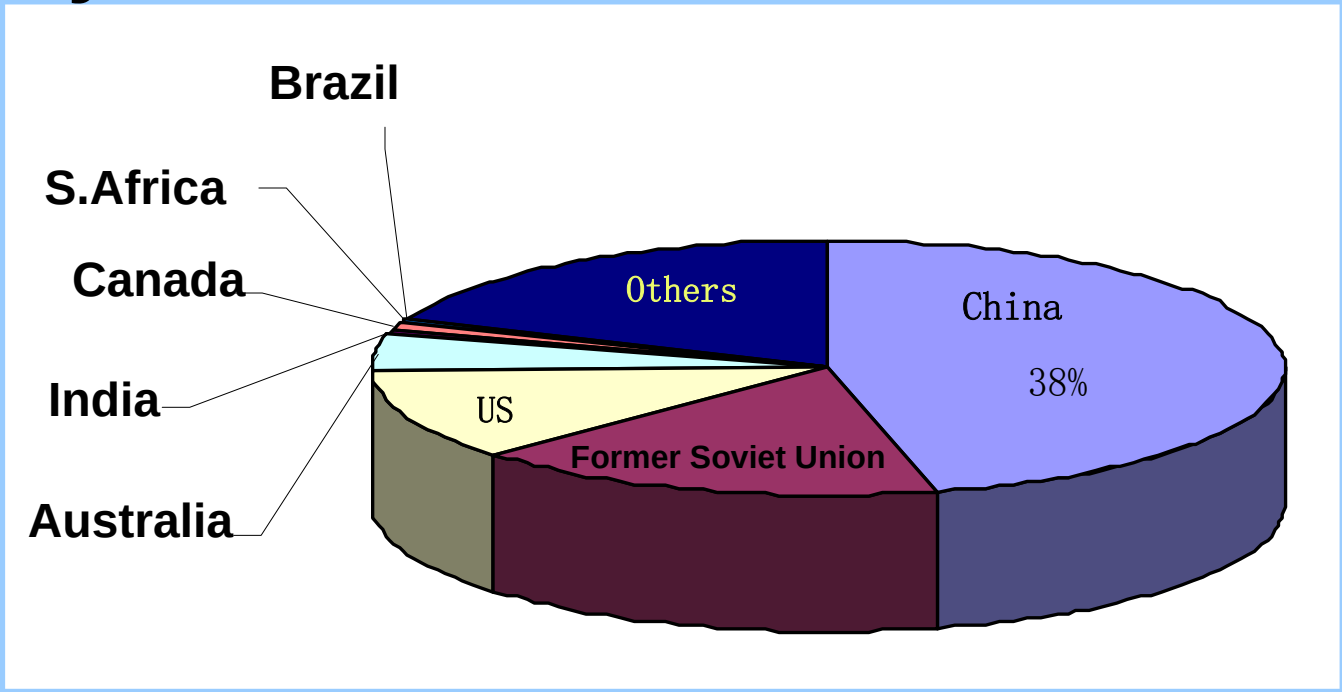
Metal and mining industries involved NORM or TENORM

Bauxite	**Lead**	**Thorium**
Beryllium	**Molybdenum**	**Tin**
Columbium	**Nickel**	**Uranium**
Copper	**Rare Earths**	**Titanium**
Gold	**Silver**	**Zinc**
Iron	**Tantalum**	**Zirconium**

Source: EPA 1993.
www.tenorm.com

1. Introduction

Industry reserve of REO

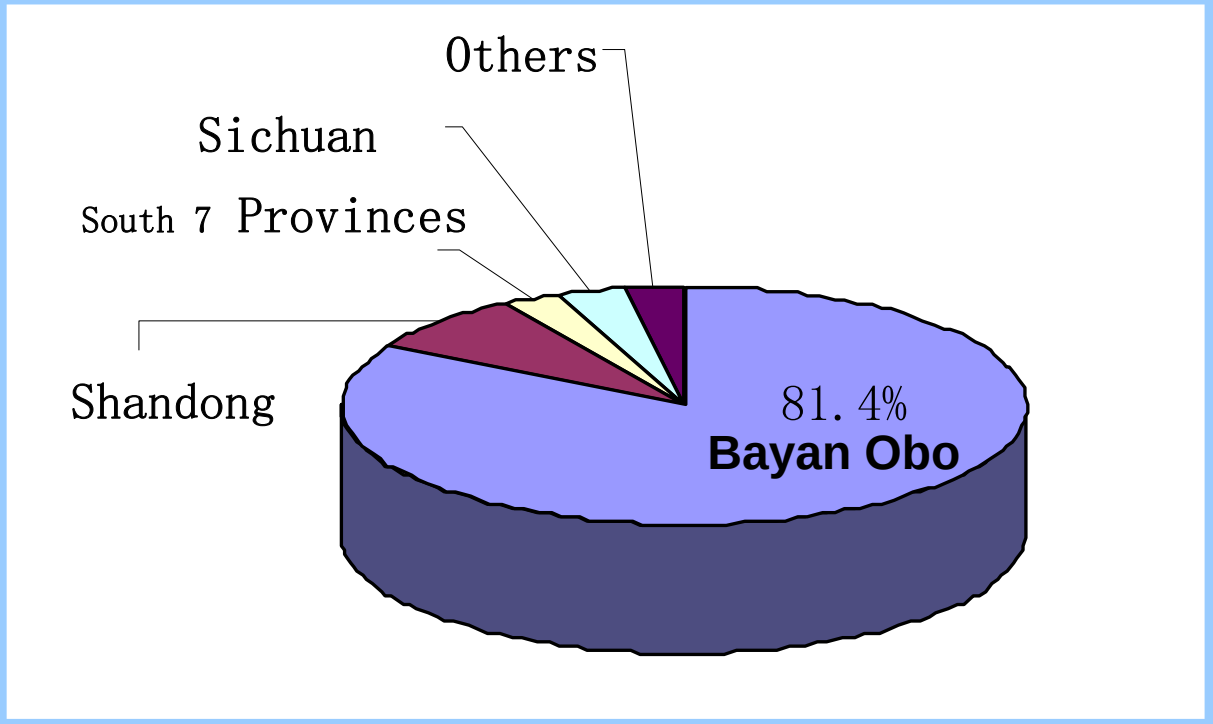


The world: about 112.7×10^6 t

China :43×10^6 t, 38%

1. Introduction

Industry reserve of REO



China :43×10⁶ t

Bayan Obo deposit : 35×10⁶ t, 81.4%

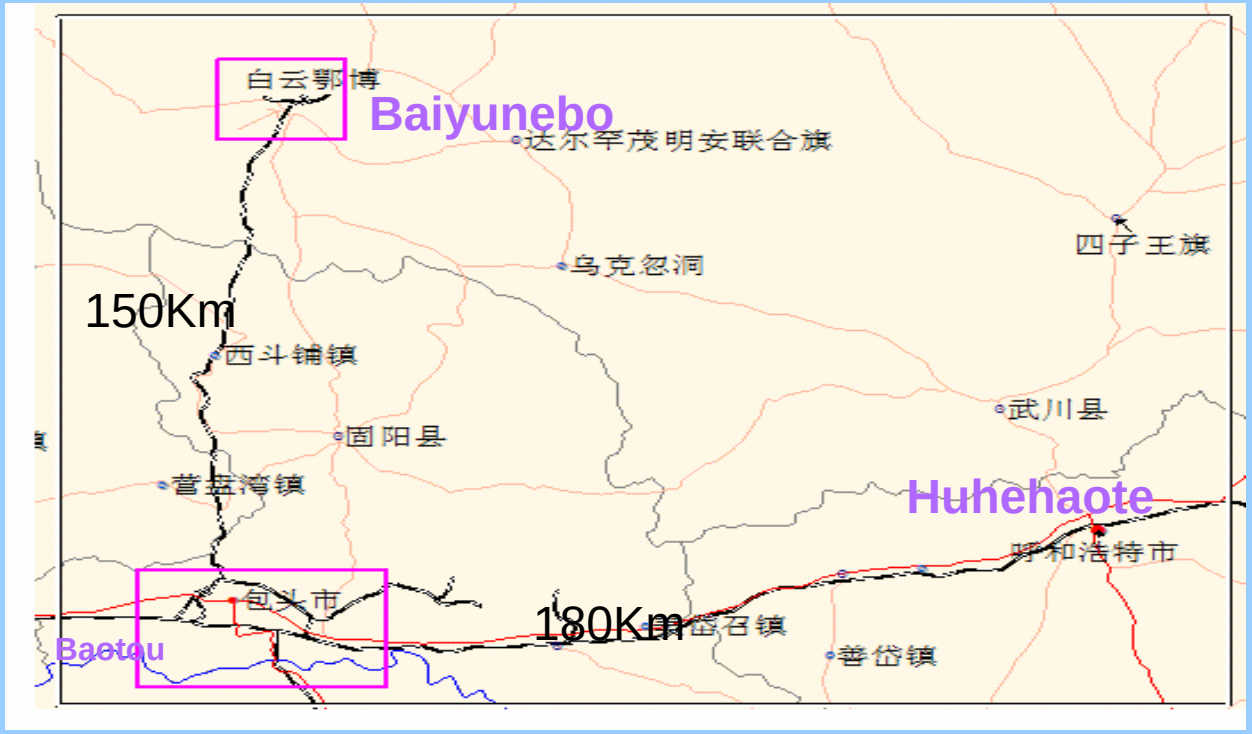
The rest about 8×10⁶ t

1. Introduction

The distribution of Rare Earth deposits in China

1. Introduction

Baiyunebo mines and processing plants

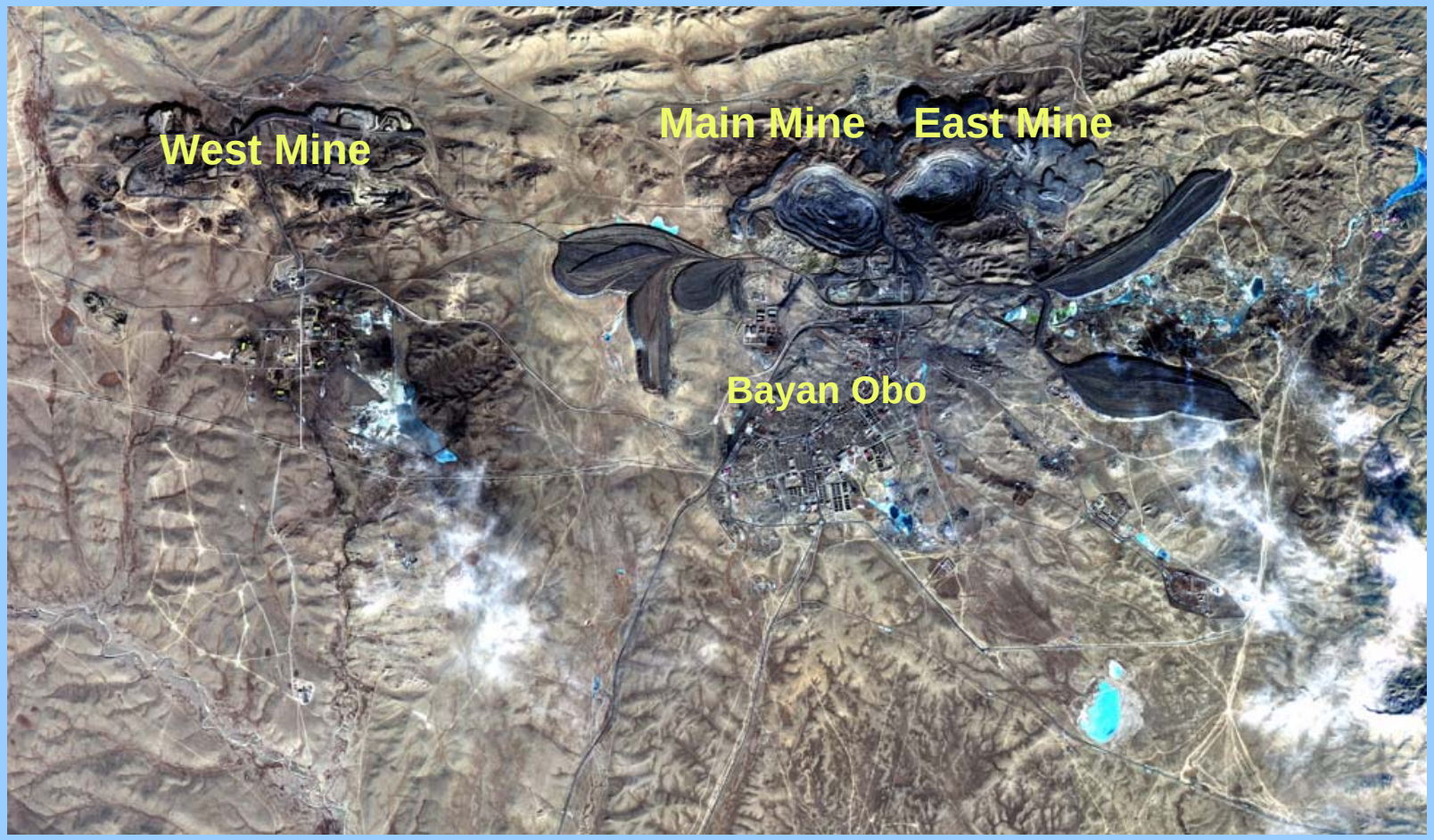


Bayan Obo mine

Main Mine and
East Mine
West Mine

Inner Mongolia **B**ao**T**ou **I**ron and **S**teel **P**lant (Group Ltd.), or BTISP, **founded in 1954, 150 km South of Bayan Obo.**

Other rare earth plants, after 1974



Bayan Obo mine: **18Km × 2 - 3Km.**

- Main Mine and East Mine have reserve of 600×10^6 t of ores containing about 34% iron, 5% REO and 0.032% ThO_2.
- West Mine has 800×10^6 t of ores with mainly 33.15% irons, but low contents of REs, thorium, phosphorus and fluorine

1. Introduction

The Bayan Obo ores are rich in thorium, so it causes a certain radiological impact on both work places and the environment during mining and processing.

2. Mining

About 276×10^6 t of ores had been mined by the end of 2006.
About 10×10^6 t/a of ores are recently mined

a big open pit mine

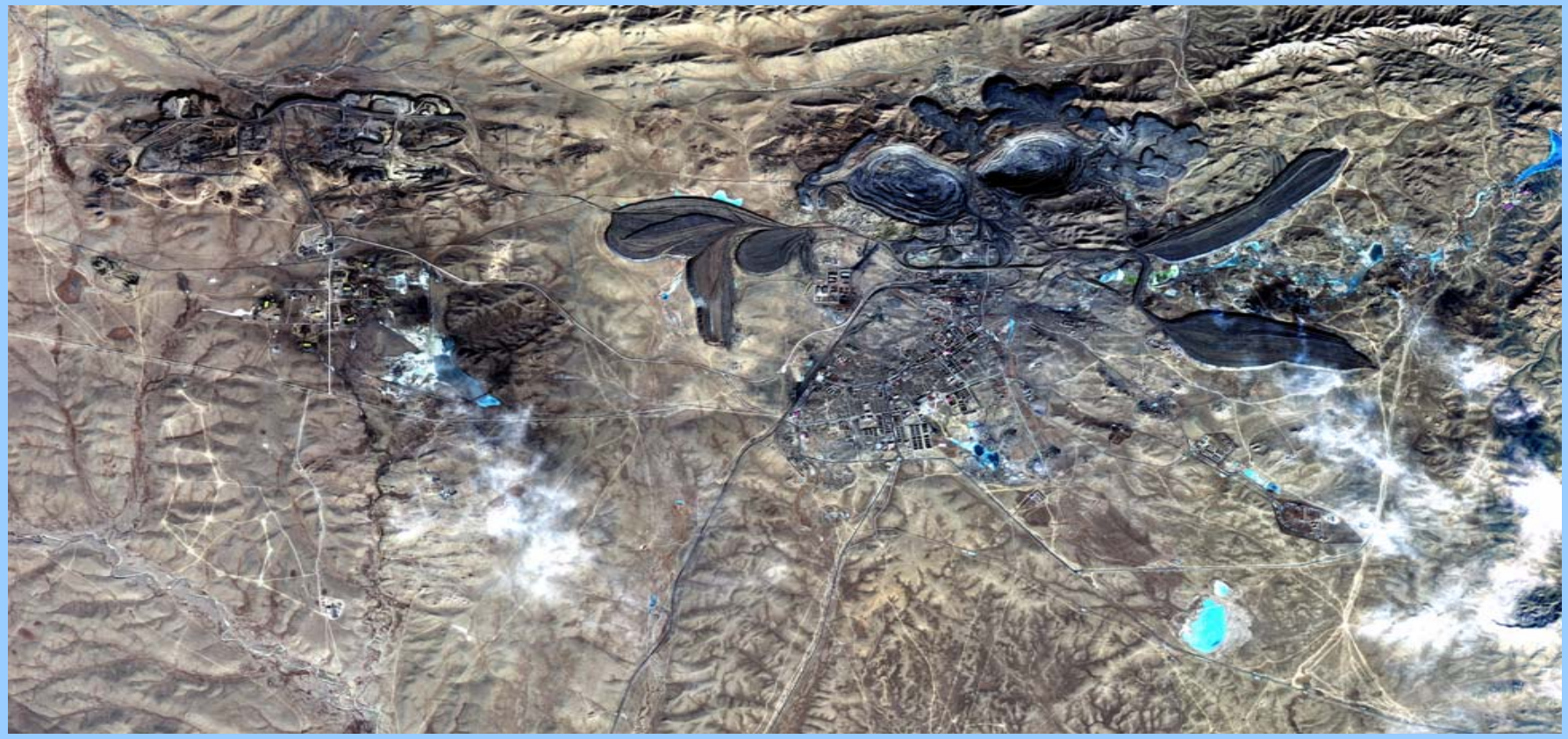
$1520 \times 1080 m^2$ for Main Mine, $1400 \times 1020 m^2$ for East Mine

2. Mining

West Mine, a big open pit mine, started in May, 2006.

4,600 m in length
1,000 m to 1,200 m in width.
The present production of ores is expected to be 3×10^6 t/a,

2. Mining



Large amount of waste rocks is generated in mining, piling up along the dumps on the mining site. About 10×10^6 t of waste rocks are produced annually.

2. Mining

Total amount of waste rocks is about 560×10^6 t , piled up in the waste rock dumps.

3. Processing

BTISP produced only iron and steel products at its early stage. It has been producing RE products from RE concentrates in line with iron and steel at the same time since 1974.

The BTISP processes 12×10^6 t/a of ores from Bayan Obo mine, produces 9×10^6 t/a of iron and steel and more than 7×10^3 t/a of oxide equivalent of REO products .

3. Processing

First step

Production of iron and RE concentrates

4.5×10^6 t/a and 100×10^3 t/a respectively

Iron concentrate contains thorium 0.024% to 0.0073%

Rare earth concentrate contains 0.2% thorium

The tailing , 6.55×10^6 t/a with 0.048% thorium

3. Processing

First step

Tailings , 149 ×10^6 t , 2006

occupying an area of 11km^2

3. Processing

Second step

Production of iron and steel, and REO

- All iron concentrates for the BTISP
- About two thirds of rare earth concentrates for the RE plants in Baotou, the rest for the plants outside Baotou.

3. Processing

Second step

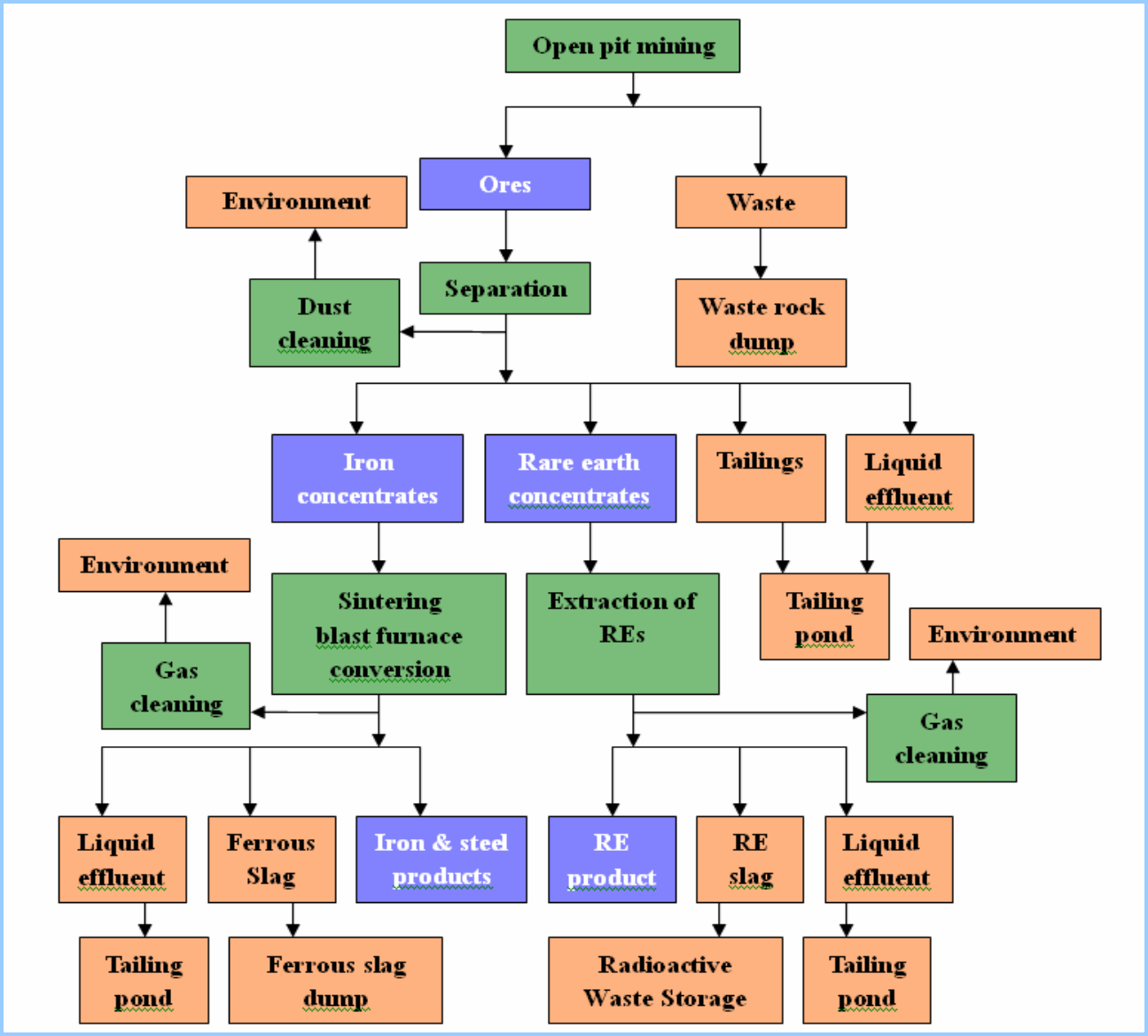
- The BTISP recently produces 9×10^6 t of iron and steel, yielding 3.55×10^6 t of ferrous slag annually

3. Processing

Second step

- There are 13 RE plants in Baotou city area.
- Products include RE oxides, RE chlorides, RE carbonates and alloy products.
- 60×10^3 t/a of RE slag is produced and disposed in Baotou Radioactive Waste Storage Facility

4. Management and utilization of Wastes



Major flow chart and pollutant production of Bayan Obo ores exploitation

4. Management and utilization of Wastes

Bayan Obo ores, 0.032% ThO_2

Radionuclide concentration in products
The iron and steel products , trace or no
RE alloys, 0.04- 0.24% Th
RE chlorides , 0.045% Th
RE oxides , 0.0069% Th.

The total amount of thorium content in ores have been redistributed in the slag
in solid waste 96-98%
in exhaust gas 0.1-0.5%
in liquid effluent 0.6-2.0%

4. Management and utilization of Wastes

The inventory of production of NORM residues (Slags)

Slag Type	2006 annual production (10^4t)	Stock record (up to 2006） (10^4t)	Storage place
Tailing	654.67	14933.7	Baogang tailing pond, Bayan tailing pond
Alloy	0.58	96.3	Baogang alloy slag dump
Blast furnace	290	5502.5	Baogang ferrous slag dump
RE	6.09	26.1	Baotou Radioactive Waste Storage Facility

4. Management and utilization of Wastes

Radiological safety in the exploitation of Bayan Obo ores and utilization of NORM residues is ensured through compliance with the law and national regulations, as well as relevant IAEA standards.

4. Management and utilization of Wastes

- **Law of the People's Republic of China on Prevention and control of Radioactive Pollution**
- **Basic Standards for Protection and Prevention against Ionizing Radiation（GB18871-2002）**
- **Regulations for Safe Management of Radioactive Wastes from the Mining and Milling of Uranium and Thorium Ores, (1993)**
- **Regulations for radioactive waste management (GB14500 – 2002)**
- **Requirement of control on radioactive substance for building material product and industrial by-product used in building materials(GB 6763-2000)**
- **Limit of radionuclides in building materials,**
- **Standard of limit on radioactive substance for industrial waste slag used in building materials(GB6763-86)**

4. Management and utilization of Wastes

- **International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).**
- **Regulatory Control of Radioactive Discharges to the Environment, Safety guide No.ws-2.3, IAEA, Vienna (2000).**

4. Management and utilization of Wastes

Baogang tailing pond

Recovery of waste water

4. Management and utilization of Wastes

The gross α activity concentration of acidic process slag is 8×10^{4}-2×10^{5}Bq/kg, exceeds the activity level of low level radioactive solid waste.

Baotou Radioactive Waste Storage Facility

4. Management and utilization of Wastes

Uses of waste rocks → road construction and the bank of tailing pond

Recovery of waste water → 64.57×10^6t /a

Recovery of acid → 45,000 t/a of sulphuric acid

The uses of blast furnace slag

→ Recovery of waste iron

→ as materials to make cement, bricks and other building products

4. Management and utilization of Wastes

brickyard

The uses of blast furnace slag

Recovery of iron

4. Management and utilization of Wastes

- **The BTISP produced blast furnace slag , 3,550,000 t/a**
- **Use of blast furnace ,about 1450,000 t/a**
- **The consumption of the slag is nearly a half based on the recent utilization rate.**
- **The usual way to produce construction materials from blast furnace slag is to mix blast furnace slag and the low radioactive material such as fly ash together. The products meet the requirements of radioactive level for construction materials.**

4. Management and utilization of Wastes

Major enterprises and their products used ferrous slag in 2007

Factories	Major products	Production	Ra-226	Th-232	K-40
			Bq/kg	Bq/kg	Bq/kg
A brick factory	paving bricks house bricks	paving bricks 52,208 m^2 ,house bricks 32,144 m^3	51	212	123
Cement factory 1	Cement	6×10^5 t	83.6	330.9	429.2
Cement factory 2	425# cement 325# cement	3.78×10^5 t	24.6	240.1	371.9

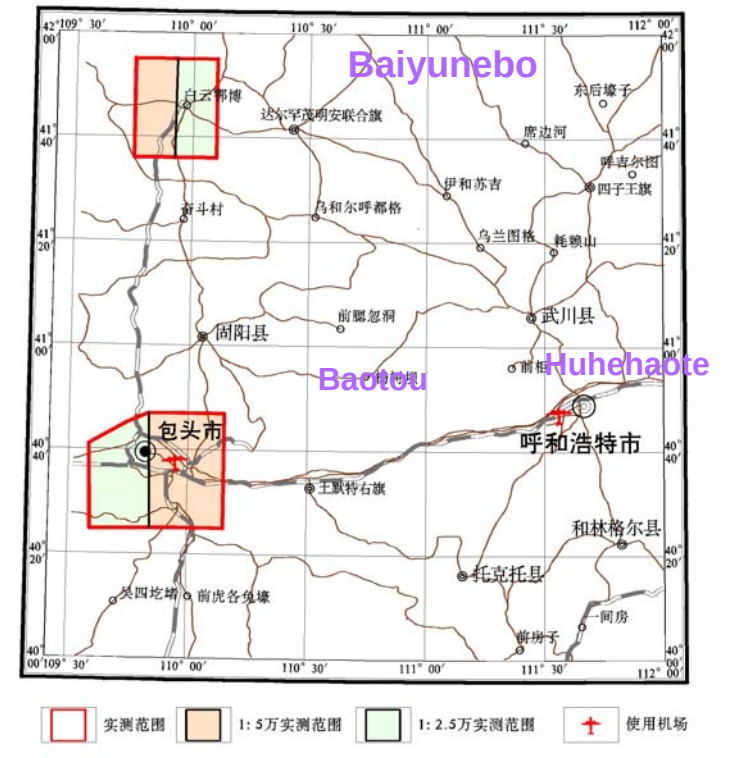
5. Exposures and environmental impact

5. Exposures and environmental impact

（1）Gamma radiation levels

The regions covering about 2060km² has been flown in 2006, by the airborne gamma spectrometry for radioactivity mapping.

The follow-up ground measure-ments to verify the elevated areas were carried out.



Baiyun:23Km×28Km

Baotou:42.5Km×30 Km

5. Exposures and environmental impact

Airborne gamma spectrometry

The AGS system was installed in fixing wings aircraft, with large volume(32L) sodium iodide (NaI(Tl))detector.

GR-820

NaI (Tl) detector

5. Exposures and environmental impact

Follow up ground work

In Situ HPGe Gamma Spectrometer

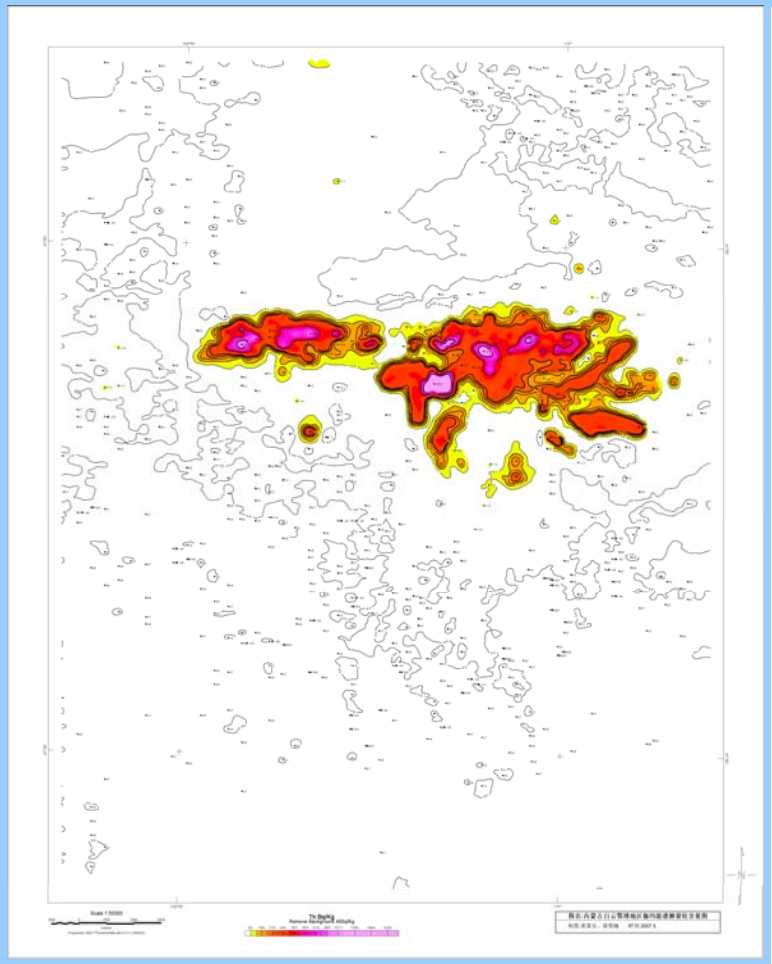
The CGS system was installed in jeep, with large volume(4L) , GR460 , NaI(Tl) detector.

5. Exposures and environmental impact

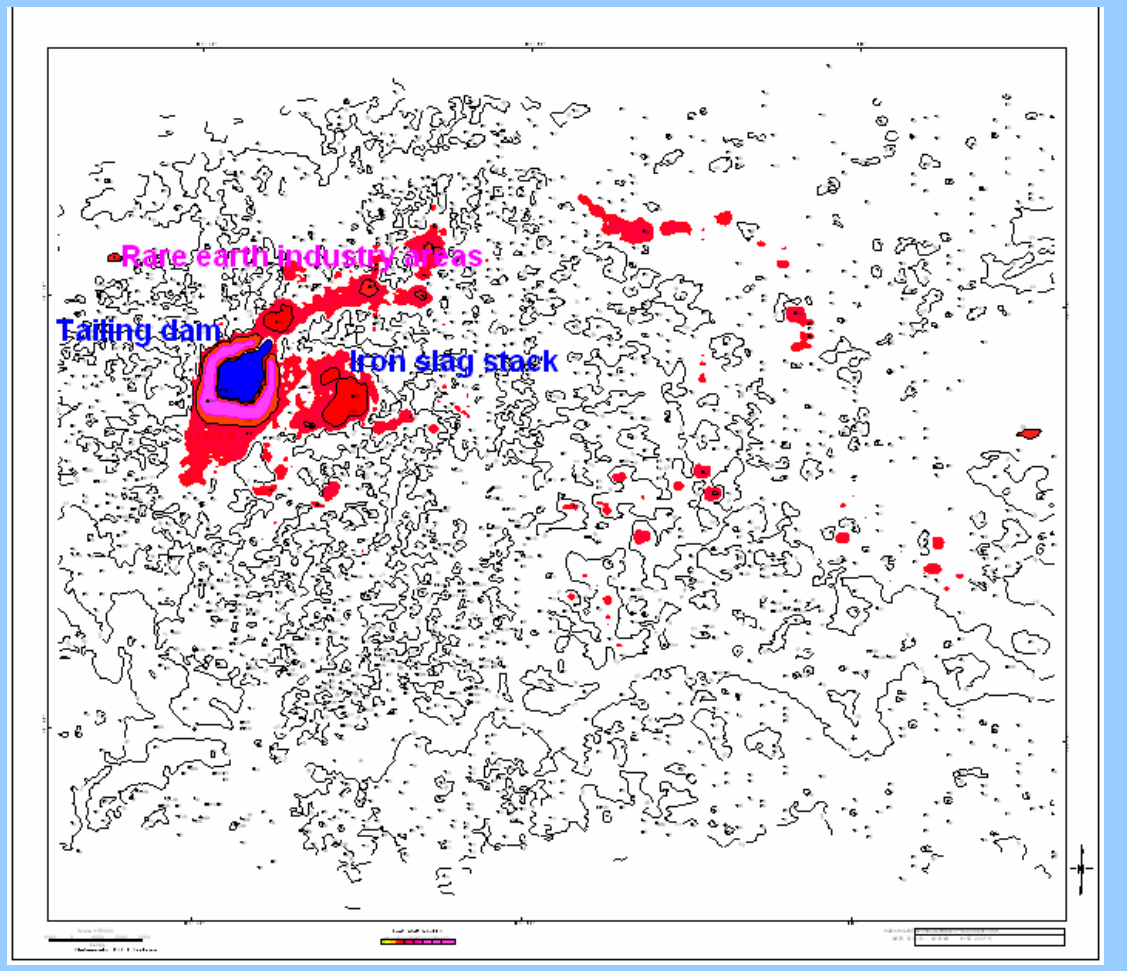
Dose meter

^{222}Rn/ ^{220}Rn and ^{220}Rn progeny
CR-39 detector

5. Exposures and environmental impact

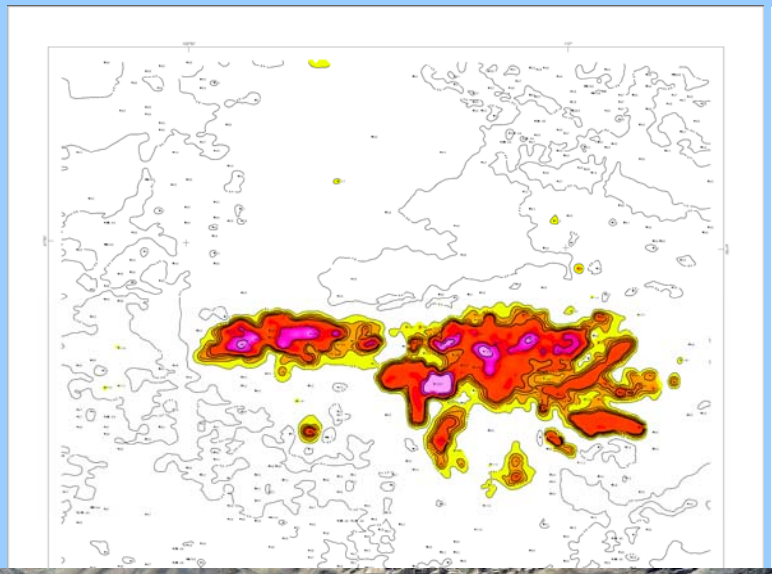


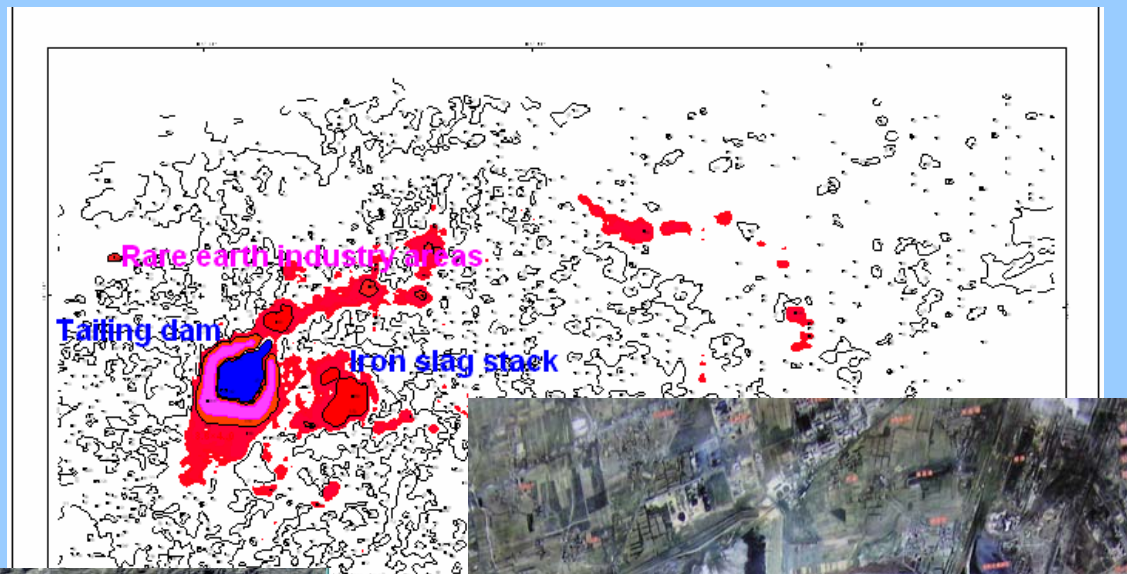
Gamma radiation levels in Baiyunebo

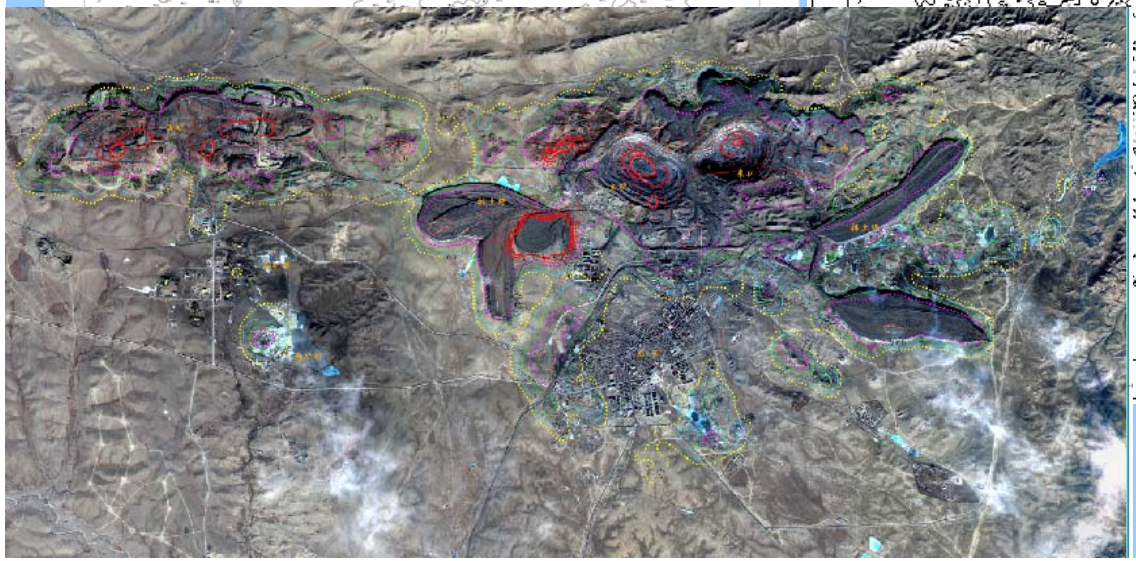


Gamma radiation levels in Baotou

5. Exposures and environmental impact







Bayan Obo

- **BG: 85nGy/h, HBG:200—800nGy/h and about 55.4 Km^2**
- **Mining sites :600 to 2000nGy/h**
- **Dumping sites: 400 to 800nGy/h**
- **The contaminated soil area:**
  - **100-150nGy/h,**
  - **80-120Bq/kg in the upper layer of 10 -20cm.**

Baotou

- **BG: 65nGy/h ,HBG: 500-1,000nGy/h and about 7 km^2**
- **Tailing pond: 650-1200 nGy/ h and 11 Km^2.**
- **Ferrous slag dump: 500-1200 nGy/ h and 0.8Km^2.**
- **The contaminated soil area:**
  - **85-150nGy/h,**
  - **80-200Bq/kg in the upper layer of 10 -20cm.**
  - **background , 50Bq/Kg.**
- **32 hot spots : 120-1200nGy/h**

hot spots : 120-1200nGy/h

abandoned rare earth plants

hot spots : 120-1200nGy/h

The plant is closed, but rare earth slag left

5. Exposures and environmental impact

(2) Exposures(Bayan obo)

- **Most of workers receive 0.24-0.7 mSv/a of additional external exposures**
- **But some workers may receive more than 1.0 mSv/a**

Public in the Bayan Obo city area

The additional external exposure is 0.044 mSv/a

5. Exposures and environmental impact

(2) exposures(Baotou)

- **(a) Occupational exposures**
- **The additional external exposures for workers are in range of 0.3-0.6mSv/a**

- **(b) Public exposures**
- **The additional external exposure is 0.043mSv/a for members of the public living in the soil contaminated area.**
- **The indoor effective dose for the buildings containing no slag is 1.86 mSv/a in Baotou City area (similar to other places in China), but the dose becomes higher than 2.0 mSv/a for most of the buildings made of slag bricks.**

6. Summary

(1) Exposures

- **Additional exposure received by members of the public is not significant**
- **but for some workers, probably exceeds 1.0 mSv/a.**

6. Summary

(2) Use and management of Norm Residues

- **Tailings and RE slag are stored as mineral reserves.**
- **larger amount of slag was used for building material that meet the radiation safety requirements.**

6. Summary

（3）Problems and Measures

- **Large amount of wastes (iron slag) is big problem, needed to reduce**
- **But when wastes are used , radioactive problems occur.**
  - A typical example of spread of NORM is the building bricks made of the residues.
  - A criterion should be set to confine the uses of NORM residues to banned, conditional and unconditional uses in terms of activity concentration of NORM residues.
  - the uses of these construction materials should be restricted.

6. Summary

（3）Problems and Measures (cont.)

- some plants are closed, but residues and wastes do not return to stack . These plants need to be decommissioned

6. Summary

（3）Problems and Measures (cont.)

- **Remediation project concerning contaminated soils has been discussed and taken into account.**
- **A campaign for survey on pollution of radioactive sources has started nationwide since 2007**

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Thank you for your attention!